Transfer Impedance as a Measure of the Shielding Quality of Shielded Cables and Connectors

1. Surface Transfer Impedance
2. Transfer Impedance vs. Shielding Effectiveness
3. Other Transfer Functions

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Definition of Surface Transfer Impedance

- In the 1930's Shelkunoff showed that Surface Transfer Impedance was the Intrinsic Electromagnetic Shielding Property of Cables Connectors and Backshells

$$Z_t = (1 / I_o)\, dV/dz$$

I_o = Current flowing on Shield

dV/dz = Voltage per unit length on inside of shield

- In practice, $Z_t = V / (\ell * I_o)$ where ℓ is cable length
- For Connectors, V is a point source

$$Z_t = V_{oc} / I_o$$

where V_{oc} is the open circuit voltage on inside of shield

Surface Transfer Impedance

- Similar to Common Impedance Coupling
- Current on one side of Barrier Produces Voltage on other side of Barrier due to Impedance of Barrier
- Surface Magnetic Field on one side of Barrier produces Tangential Surface Electric Field on other side of Barrier due to Impedance of Barrier
- At Low Frequencies, Impedance is Resistance due to Current Diffusion and Contact Resistance
- At High Frequencies, Impedance is Mutual Inductance due to Apertures, Porpoising, Etc.

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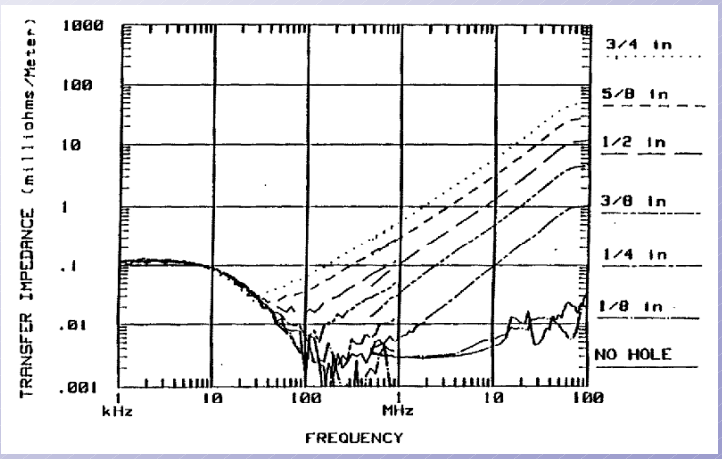
Measured Surface Transfer Impedance of 1-1/4" Diameter Cu Pipe with a Single Hole



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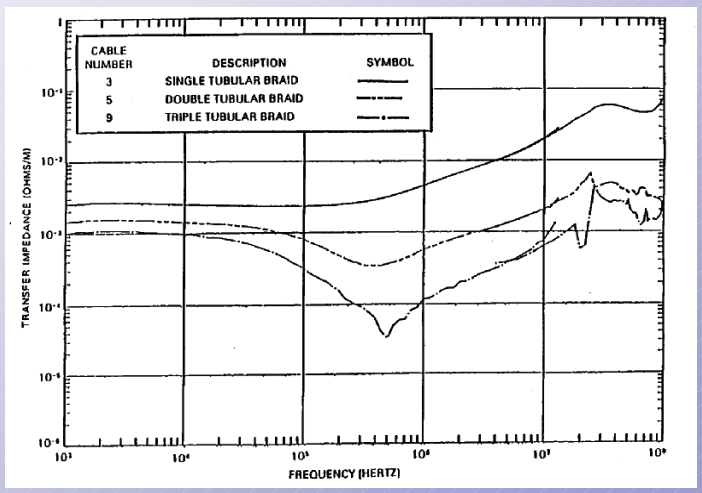
Surface Transfer Impedance of Braided Cable



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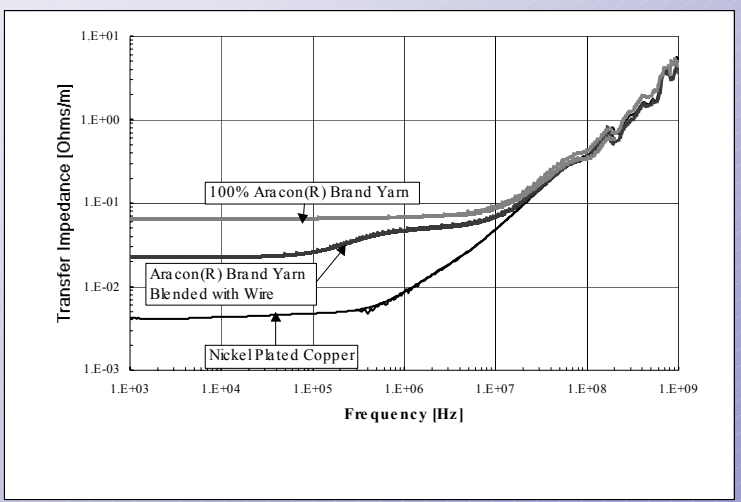
Surface Transfer Impedance of Metal Clad Aramid Fiber Cable Shields



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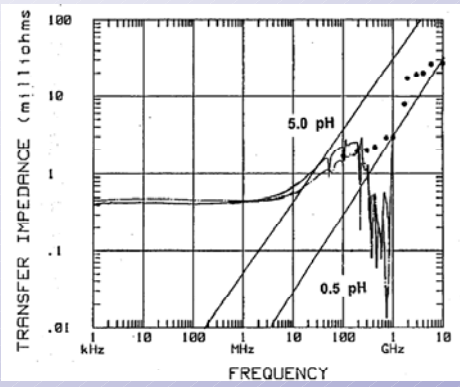
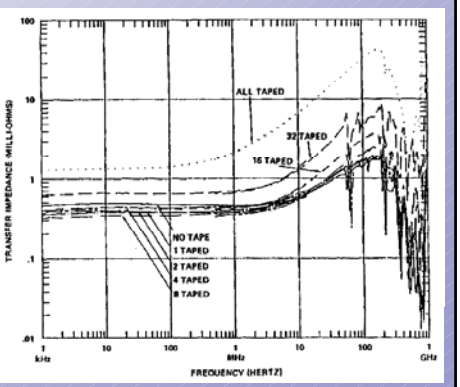
MIL-C-38999 Series IV Circular Connector with Backshell and Braid Termination

Mil-C-38999 Requirements Converted Into Transfer Impedance



Effect of Spring Fingers on Transfer Impedance



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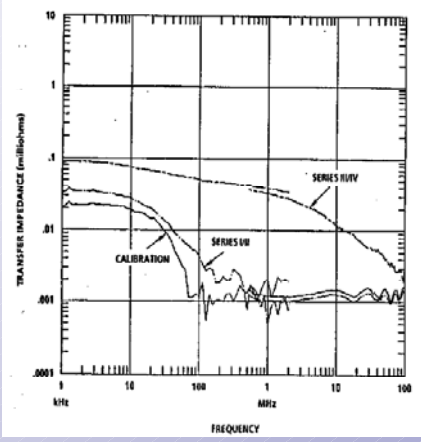
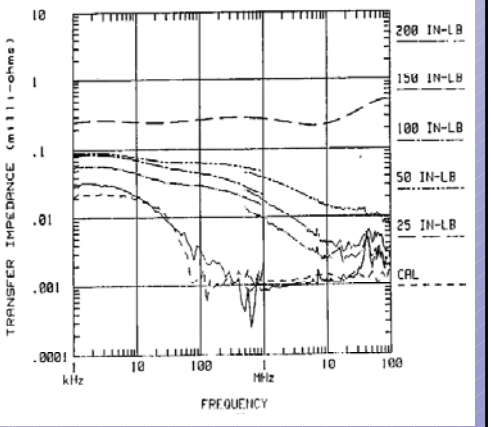
Transfer Impedance of Samples Using the MIL-C-38999 Connector/Backshell Interface

Initial Measurements



Effect of Torque



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Surface Transfer Impedance vs. Shielding Effectiveness

- Conceptually, Surface Transfer Impedance can be used until the Circumference becomes Electrically Large
- Practically, Surface Transfer Impedance becomes Difficult to Measure above a GHz
- Shielding Effectiveness is another kind of Transfer Function
  - Originally Based on Insertion Loss Concept
  - Often Ratio of a Parameter at Two Places
  - Not an Intrinsic Property
  - Depends on Interior and Exterior Impedances
  - No Standard Shield
- When Sample is Electrically Large, Stirred Mode Shielding Effectiveness may be Appropriate

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Stirred Mode Shielding Effectiveness

- Definition:
  - Shielding Effectiveness = Exterior Power Density/Power Flowing Out of Cable into Load
- Apertures are Principle Coupling Mechanism
- Shielding Effectiveness depends not only on Apertures, but also on Load and Characteristic Impedances.
- Theory is available for converting Transfer Impedance to Stirred Mode SE and vice versa

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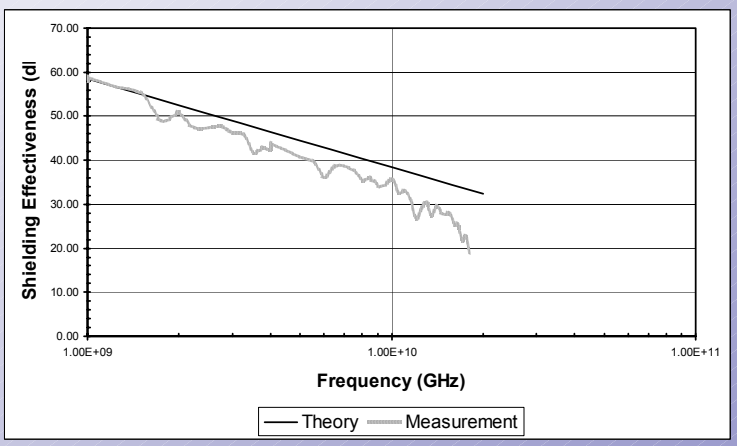
Stirred Mode Shielding Effectiveness of Shield Artifact

Type N Barrel with two 6.35 mm Holes



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Other Transfer Functions

- Normally, Surface Transfer Impedance assumes that the Current Flow and the resulting Electric Field are both Longitudinal.
- Broyde defines and demonstrates Transfer Impedances where Current Flow and Electric Field are Transverse and in some cases Orthogonal.

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Surface Transfer Admittance vs. Charge Transfer Elastance

- **Surface Transfer Impedance defines the Longitudinal Electric Field on one side of a Cable Shield resulting from a Surface Magnetic Field on the other side.**
- **If the Cable is in a Region of High Electric Field, its Effect must be evaluated:**
  - Surface Electric Field is Normal to Surface.
  - Surface Transfer Impedance does not describe the situation.
  - Surface Transfer Admittance, the compliment of Surface Transfer Impedance, is not appropriate because it is not an Intrinsic Characteristic of the Shield
- **Surface Charge Transfer Elastance, or Through Elastance, is the appropriate Characteristic**

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Surface Charge Transfer Elastance

- **Definition: Surface Charge Transfer Elastance or S_s Parameter, is the ratio of the Transfer Capacitance to the Internal and External Capacitances.**
  - An Electrical Elastance is the inverse of a Capacitance.
  - Internal and External Capacitances are normalized out.
  - Should be Frequency Independent
  - No resistive component, only capacitive
  - Measured at Low Frequencies, before Capacitively Coupled Currents generate Voltages/Currents via Transfer Impedance Coupling

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Summary

1. Surface Transfer Impedance is the Intrinsic Electromagnetic Property for Characterizing Shields
2. Shielding Effectiveness is not an Intrinsic Property of a Shield, but is useful at frequencies where the Sample is Electrically Large
3. Charge Transfer Elastance may be useful is Regions of high Electric Field

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Selected References

1. Edward F. Vance, "Coupling to Shielded Cables," Wiley-Interscience, New York, 1978.
2. Lothar O. Hoeft and Joseph S. Hofstra, "Measured Electromagnetic Shielding Performance of Commonly used Cables and Connectors," IEEE Transactions on EMC, Vol. 30, No. 3, Part 1, August 1988.
3. Lothar O. Hoeft, "Comparison of the Electromagnetic Shielding Provided by Circular and Rectangular Connectors and their Accessories," Proceedings of the IICIT 26th Annual Connectors and Interconnection Technology Symposium, Sept 1993.
4. B. T. Szentkuti, "Shielding Quality of Cables and Connectors: Some Basics," Record of the 1992 International IEEE Symposium on Electromagnetic Compatibility, Anaheim, CA, August 1992, pp 294-301.
5. B. Eicher and L Boillot, "Very Low Frequency to 40 GHz Screening Measurements on Cables and Connectors; Line Injection Method and Mode Stirred Chamber," Record of the 1992 International IEEE Symposium on Electromagnetic Compatibility, Anaheim, CA, August 1992, pp 302-307.
6. Lothar O. Hoeft, "A Simplified Relationship Between Surface Transfer Impedance and Mode Stirred Chamber Shielding Effectiveness of Cables and Connectors." Record of the EMC Europe 2002 International Symposium on Electromagnetic Compatibility, Sorrento, Italy, September 2002, pp 441-446
7, F. Broydé, E. Clavelier, "Characterization of a Cylindrical Screen for External Excitations and Application to Shielded Cables", IEEE Transactions on EMC, Vol. 44, No. 4, November 2002, pp. 580-588.

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